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Findlay, Holly; Carrol, Gareth

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Running Head: SEMANTIC RICHNESS AND IDIOM PROCESSING

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Holly Findlay and Gareth Carrol

University of Birmingham

Address for correspondence:

Gareth Carrol, Department of English Language and Linguistics, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom

Email: g.carrol@bham.ac.uk

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Abstract

Idiom studies typically consider variables such as familiarity, decomposability and literal plausibility, and the contributions of these variables to how figurative phrases are processed are well established. In this study we consider the effect of a previously untested variable: semantic richness. Semantic richness refers broadly to the range of semantic information denoted by a lexical item, and reflects features such as imageability, number of senses, semantic neighbourhood, etc. This has generally been restricted to single words and sometimes to metaphors, so here we investigate how some aspects of this measure – specifically those reflecting perceptual characteristics – contribute to the processing of idiomatic expressions. Results show that aspects of semantic richness affect idiom processing in different of ways, with some (emotional valence) contributing to faster processing of figuratively related words, and others (those that highlight physical and literal aspects of the idiom) showing an inhibitory effect. We also show that for some of the dimensions of semantic richness considered here, there is a significant correlation between a measure constructed from the ratings of component words, and one gathered from ratings for the phrase as a whole, suggesting a straightforward way to operationalise semantic richness at a multiword level.

Key words: semantic richness, idioms, cross-modal priming

The study of idioms has shown that a range of factors are important in how they are recognised, processed and understood. There is broad agreement that they have at least some level of representation in the mental lexicon – as per the Configuration Hypothesis (Cacciari & Tabossi, 1988) or more recent hybrid models such as the Superlemma account (Sprenger, Levelt & Kempen, 2006) – but the way that this is accessed is affected by such properties as individual familiarity (Cronk & Schweigert, 1992; Libben & Titone, 2008; Schweigert, 1986, 1991; Titone & Connine, 1999), decomposability (Caillies & Butcher, 2007; Titone & Connine, 1999), and literal plausibility (Titone & Connine, 1994). Titone and Libben (2014) showed that each of these has its own effect on activation of idiom meaning at different points during processing, and proposed a view where figurative meaning accrues over time, modulated by different variables.

One feature that has received attention in the context of single words but, to our knowledge, has not been considered for idioms, is semantic richness. Semantic richness has been defined variably in the literature, but broadly refers to "the amount of semantic information associated with a concept" (Kounios, Green, Payne, Fleck, Grondin & McRae, 2009, p. 95). Rich concepts are those that are considered to have strong, well-developed semantic networks, as measured by dimensions such as number of semantic features (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008); semantic neighbourhood density (Buchanan, Westbury, & Burgess, 2001); number of senses (Rodd, 2004; Woollams, 2005); number of first associates (Duñabeitia, Avilés & Carreiras, 2008); imageability (Cortese & Fugett, 2004); body-object interaction (Siakaluk, Pexman, Aguilera, Owen & Sears, 2008); sensory experience rating (Juhasz & Yap, 2013); emotional valence (Kousta, Vinson & Vigliocco, 2009; Yap & Seow, 2014); and contextual dispersion (Pexman et al., 2008). Broadly, number of features,

neighbourhood density, number of senses and number of associates can be categorised together as relating to the strength of connection to the semantic network. Imageability, physical interaction, sensory experience and emotional valence all relate to the perceptual strength of a given concept. The final feature (contextual dispersion) considers the degree to which a concept appears across different contexts. The effect of increased connectivity to the semantic network has been shown to have a robust facilitative effect, as shown by large scale studies such as Pexman et al. (2008), Yap, Tan, Pexman and Hargreaves (2011) and Yap, Pexman, Wellsby, Hargreaves and Huff (2012), using a range of word recognition and classification tasks. Similarly, concepts with higher ratings for perceptual characteristics have been shown to be processed more quickly than those with lower ratings (Cortese & Fuggett, 2004; Juhasz & Yap, 2013; Siakaluk et al., 2008), and words with a strong valence (either positive or negative) generate faster responses than neutral words (Yap & Seow, 2014).

Alongside the contribution of semantic richness to the processing of single words, some researchers have also considered how this set of variables may influence processing of metaphors, where the meaning of a word is extended to encompass an additional, figurative meaning. Al-Azary and Buchanan (2017) found that both suitability judgments and online comprehensibility of metaphors were affected by concreteness (more abstract metaphors were facilitated) and semantic neighbourhood density (sparser neighbourhoods were facilitative). They also found an interaction between these two properties which they suggest may explain the variable results obtained for concreteness in previous metaphor studies (e.g. Harris, Friel & Mickelson, 2006; Xu, 2010), and predictions about semantic neighbourhood made by Kintsch (2000) and Katz (1992), both of whom suggested that denser neighbourhoods should aid

metaphor comprehension. The perceptual qualities of a metaphor, and in particular the imagery it evokes, have also been argued to be important for how it is understood (Paivio & Clark, 1986; Ojha & Indurkhya, 2016).

Given that a range of literal and non-literal language processing seems to be influenced by semantic richness, it seems logical to ask how these properties might also map onto idioms and other multiword units. Contrary to metaphors, the figurative meanings of idioms are (at least to some degree) retrieved directly (Titone and Libben, 2014), rather than actively worked out by analogy or metaphorical mappings. As such, any literally plausible idiom has, by definition, at least two senses (the literal interpretation and the figurative meaning of the phrase as a whole), hence idioms may automatically be more semantically rich than literal phrases in terms of a variable such as "number of senses". However, as is widely noted in the literature, idioms are not simply the sum of their parts, and differ in a number of important ways. In non-decomposable idioms such as *kick the bucket*, the individual words do not contribute their usual meanings, hence connectivity between the (figurative) meaning of the phrase and the constituent words may be low. In other cases, such as *spill the beans*, component words may acquire additional senses that do not apply except in the context of the idiom, for instance the meaning of "secret" for *beans*, and overall connectivity between individual words and the phrase itself may be high. Caillies and Butcher (2007) considered the differences between decomposable and non-decomposable idioms in terms of connectivity, citing the Construction Integration (CI) model (Kintsch, 1998). In this model, which is a more general model of textual comprehension, increased connectivity between elements at the propositional level facilitates processing. That is, decomposable idioms should be more highly connected to the semantic network than

non-decomposable ones, on the grounds that the overall phrasal meaning is at least partly linked to the propositional meaning of the component words.

For idioms, the contribution of the set of features relating to perceptual strength is also unclear. Whilst it seems logical that more decomposable idioms should correspond to more highly interconnected entries in the semantic network, the same does not necessarily seem obvious for properties such as imageability. For instance, one could just as easily envisage *kicking the bucket* as *spilling the beans*, but these differ markedly in how decomposable they are considered to be. A key question in models of idioms has been how much the literal meaning gets "switched off" once the idiom is recognised as a figurative phrase (e.g. Cacciari & Tabossi, 1988; Smolka, Rabanus & Rösler, 2007). Since literal plausibility interferes with the activation of idiomatic meaning (Titone & Connine, 1994; Titone & Libben, 2014), higher levels of richness as measured via perceptual characteristics might actually have the opposite effect for idioms as for single words, i.e. more imageable phrases may draw focus to the literal meaning, at the expense of the intended figurative interpretation. This effect might be contingent on the decomposability of each phrase, hence more decomposable phrases that have high levels of imageability or physical interaction might be facilitated if the links between the literal and figurative meanings are enhanced, whereas when the figurative meaning requires the literal meanings of words to be entirely ignored, semantic richness may be more inhibitory.

An alternative is that semantic richness may lead to overall facilitation for idioms, as it enhances their entry in the mental lexicon and therefore facilitates processing, as has been seen for single words. Here, familiarity may modulate any effect, as this has been proposed to influence how idioms are represented and understood, regardless of whether

they are decomposable or not (e.g. Abel, 2003; Carrol, Littlemore & Dowens, 2018; Libben & Titone, 2008). Semantic richness in general may therefore have the effect of enhancing activation of idiom meaning for highly familiar phrases, while effects for less familiar phrases (which are less strongly encoded in the lexicon) may be less apparent.

In this study, we specifically set out to test the contribution of the perceptual characteristics of idioms, given the varying results obtained for single (literal) words and metaphors. This is important, as an integrated theory of language needs to account for meaning units at all levels, hence comparing effects for phrases allows us to evaluate how far the findings relating to individual words apply to longer phrases with a single semantic entry. How we should go about calculating semantic richness for a phrase also remains an open question since (as noted above) idioms are not simply the result of combining individual words. An additional aim here is therefore to test the efficacy of a method for calculating phrase-level semantic richness, based on the combined properties of the words that make up each idiom.

Method

Materials

Idioms for this study were selected from Libben and Titone (2008). From their list of 210 phrases, 42 verb-x-noun idioms were selected based on the criteria that a) they were common in British English; b) they had been rated as reasonably familiar by Libben and Titone's participants (minimum familiarity rating was 2.48/5); and c) norms required for calculating semantic richness were available (see following section; a list of stimuli is available in the appendix). Single word targets related to the figurative meaning were

generated by asking six volunteers to write one word that summarised the idiom for each phrase. Words that appeared three or more times were selected as the target, with minor adjustments to ensure consistency of length (e.g. "revealed" was shortened to "reveal"). A random word generator was used to create unrelated target words, which were checked to ensure that there was no connection with an idiom's literal or figurative meaning, and which were matched with related words for frequency (measured on the Zipf scale – Van Heuven, Mandera, Keuleers, & Brysbaert, 2014)[1]. Related and unrelated target words were matched for length (related, mean = 6.1 letters, SD = 0.8; unrelated, mean = 6.1, SD = 0.5) and Zipf frequency (related, mean = 4.5, SD = 0.7; unrelated, mean = 4.6, SD = 0.5). Paired samples *t*-tests showed no differences between related an unrelated words for either variable (length: $t(41) = 0.32$, $p = .750$; Zipf frequency: $t(41) = -1.10$, $p = .279$).

Semantic richness was calculated for each idiom by obtaining individual ratings for the component words for two characteristics: imageability (taken from the MRC Psycholinguistic database – Coltheart, 1981) and sensory experience (taken from Juhasz and Yap, 2013). These were chosen as the ratings were freely available, hence provided a straightforward way to calculate phrase level ratings. In the MRC Psycholinguistic database, three sets of norms (Paivio et al., 1968; Gilhooly & Logie, 1980; Toglia & Battig, 1978) were combined to create each imageability rating, expressed as a score on a scale from 1 (not arousing any image) to 7 (strongly arousing a mental image). Sensory experience ratings (SER) were collected by Juhasz and Yap (2013), and this consisted of asking participants to rate on a seven-point scale the extent to which a word evokes a taste, touch, sight, sound, or smell.

We calculated a composite measure of semantic richness by summing the scores for imageability and SER for each content word, then for the phrase as a whole, as shown in Table 1.

Table 1. *Method of calculating composite semantic richness for the idiom "take the plunge" (SER = Sensory experience ratings).*

			Semantic richness	
	Imageability	SER	Word	Phrase
take	3.37 / 7	1.92 / 7	5.29 / 7	13.47 / 28
plunge	5.48 / 7	2.70 / 7	8.18 / 7	

The overall mean semantic richness score was 15.4 (SD = 1.7), with a maximum of 19.2 and a minimum of 10.6. Items were counterbalanced over two lists, with the related and unrelated target item for each idiom appearing on opposite lists (List A, mean = 14.8, SD = 1.7; List B, mean = 15.9, SD =1.7; $t(20) = -1.85$, $p = .080$).

Procedure

Idioms were included in a cross-modal lexical decision task programmed in e-Prime version 2.0 (Psychology Software Tools). Cross-modal priming is widely used in idiom studies to measure the extent to which a figurative meaning is activated (e.g. Cacciari & Tabossi, 1988; Titone & Libben, 2014), so presents a suitable method here. Participants heard each phrase in the form pronoun-idiom, e.g. *he blew a fuse*, then at 500ms after

the offset of the phrase were presented with a target word and asked to make a lexical decision by pressing yes (with their right hand) or no (with their left hand) on a serial response button box.[2] To avoid any unconscious cues that might bias listeners toward figurative or literal interpretations (van Lancker, Canter & Terbeek, 1981), idiom prime sentences were presented using an online text-to-speech converter with a British, female voice (www.fromtexttospeech.com). Targets were presented in black in 18-point Courier New font in the centre of the screen. For each trial participants heard either an idiom or filler phrase of the same structure (e.g. *he ate the cake*). Idioms were followed by a word related to either the figurative meaning or an unrelated word. Fillers were always followed by a non-word (generated by the ARC Nonword Database – Rastle, Harrington & Coltheart, 2002), which was matched with the target words for length. We note here that the arrangement of items may present something of a confound, in that word responses were always preceded by an idiom, whereas non-word responses were always preceded by a non-idiom control phrase. This was done to maximise the sample size in terms of items (i.e. splitting the idioms up so that some where followed by non-words would halve our pool of analysable data), and does not preclude us from pursuing the main aim of the study, which is to look at the specific effects of sematic richness on activation of figurative meaning. We address these methodological issues further in the Discussion.

Participants were 68 native speakers of British English and were undergraduate students at a UK university. Each participant saw a total of 94 trials: 10 practice items, then 42 idioms and 42 fillers (presented in random order). Equal numbers of participants saw either version A or version B of the stimuli (see appendix for stimuli).

Analysis

Two participants were removed for technical reasons, and all practice and filler items were removed. Mean accuracy on the lexical decision task was calculated and one participant with a score of 60% was removed (all others had accuracy greater than 80%). For the remaining 65 participants, incorrect answers were removed, as were response times greater than 2500ms (total data loss of 2.3%), leaving 2667 data points for analysis. Comparison of the raw response times for the related and unrelated conditions showed an overall mean of 698ms (SD = 259) for words related to the figurative meaning of the idiom, and 716ms (SD = 256) for words unrelated to the figurative meaning of idiom.

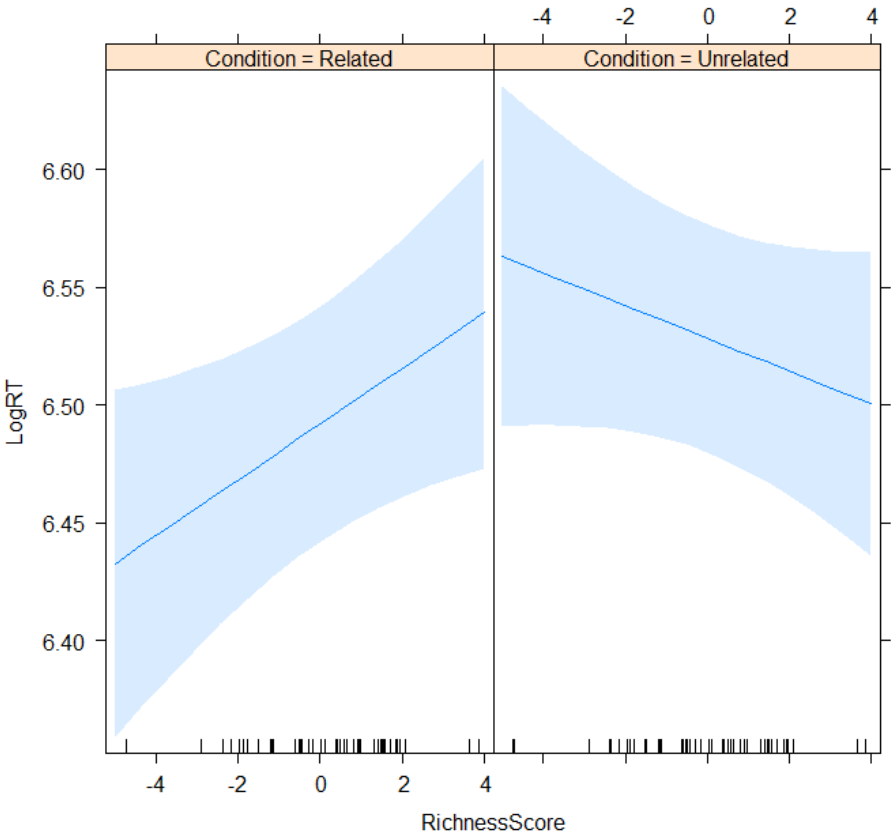
Analysis was conducted using R (version 3.4.4; R Core team, 2013) and R Studio. Linear mixed-effects models were fitted using the lme4 package (version 1.1-19; Bates et al., 2014), significance values were extracted using the lmerTest package (version 3.0-1; Kuznetsova, Brockhoff & Christensen, 2017), and effects plots were produced using the Effects package (version 4.0-3; Fox & Weisberg, 2018). Response times were log-transformed to reduce skewing. Throughout the analysis, all continuous variables are centred. We first fitted a linear mixed-effects model to determine the effect of condition (related vs. unrelated word; in all models this is treatment-coded so that baseline = related) with log-RT as the dependent variable. We included length and Zipf score for the target word, length and Zipf score for the idiom[3], and trial order as covariates. Subject and item were included as random effects, with by-subject random slopes for the effect of condition. The initial model confirmed a significant effect of condition (β = 0.04, t(64.0) = 3.37, p = .001), whereby words related to the idiomatic meaning of each phrase were responded to more quickly than unrelated control words.

Each of trial order (t = -9.71, p < .01), target length (t = -3.28, p = .001) and target frequency (t = -8.74, p < .001) had a significant effect on RTs, but none of these variables interacted with condition.

Semantic Richness

To explore the contribution of semantic richness, we added the composite score to the model as an interaction with condition. Here, as well as significant effects for condition and the other covariates, as above, there was a lower order effect of semantic richness (β = 0.02, t(76.9) = 2.13, p = .036) and an interaction with condition (β = -0.03, t(2529) = -3.43, p < .001). These results suggest a clear effect of semantic richness in inhibiting the figurative meaning of idioms, as demonstrated in Figure 1.

Figure 1. Effects plots showing that composite semantic richness score is inhibitory for figuratively related words (left) but not unrelated words (right) for idioms.



We next considered whether the two components of the composite richness score (imageability and SER) exert separate influences. We constructed a model including the interaction of condition with these two ratings separately, and compared this to the previous model, which revealed a marginal improvement (χ^2 (2) = 5.48, p = .065). In this model, imageability (β = 0.03, t(81.3) = 2.73, p = .008) had a significant inhibitory effect on related words, but SER (β = 0.00, t(70.5) = 0.37, p = .715) had no effect. The inhibitory effect of imageability suggests that when a phrase is easier to envisage, this interferes with the activation of idiom meaning, presumably because focus is drawn to the physical (therefore literal) interpretation. SER, on the other hand, has no such effects.

Given that the two components of semantic richness considered here seem to have different effects, we next considered whether a wider set of ratings might give us a better picture of how semantic richness contributes to figurative activation. We also wanted to explore how these properties relate to the established idiom variables of familiarity, decomposability and literal plausibility. To achieve this, we collected three new sets of ratings: physical interaction, emotional valence, and imageability for the whole phrase. We also obtained ratings for all of the idioms for the three idiom dimensions from the list of norms provided by Libben and Titone (2008).

Collection of additional ratings for semantic richness

We inserted each of the idioms and control phrases from the main study into an online rating study, whereby participants were asked to read each phrase (presented in the same form as in the main experiment) and provide ratings on a 5-point scale for three properties: the extent to which a mental image could be created (imageability); the extent to which the idiom involves physical interaction (body-object interaction); and the extent to which the idiom has an emotional meaning (emotional valence). The instructions provided examples of one literal (*throw a ball*) and one figurative (*lose your head*) phrase. Participants (n = 48) were native speakers of British or American English, and data was collected online via Amazon Mechanical Turk. The inclusion of a rating for imageability here was intended to give us a way of directly comparing with our original rating (i.e. comparison of a rating obtained by summing established norms for each content word, and a separate measure based on participants rating the whole phrase).

We computed correlations among the five measures of semantic richness (two original word-by-word measures, three additional phrase-level measures), and also compared these with the established idiom variables of familiarity, decomposability and literal plausibility. For ease of comparison, all variables were normalised to appear on a five-point scale. A summary of these ratings (means, SDs, ranges) and their correlations are presented in Table 2.

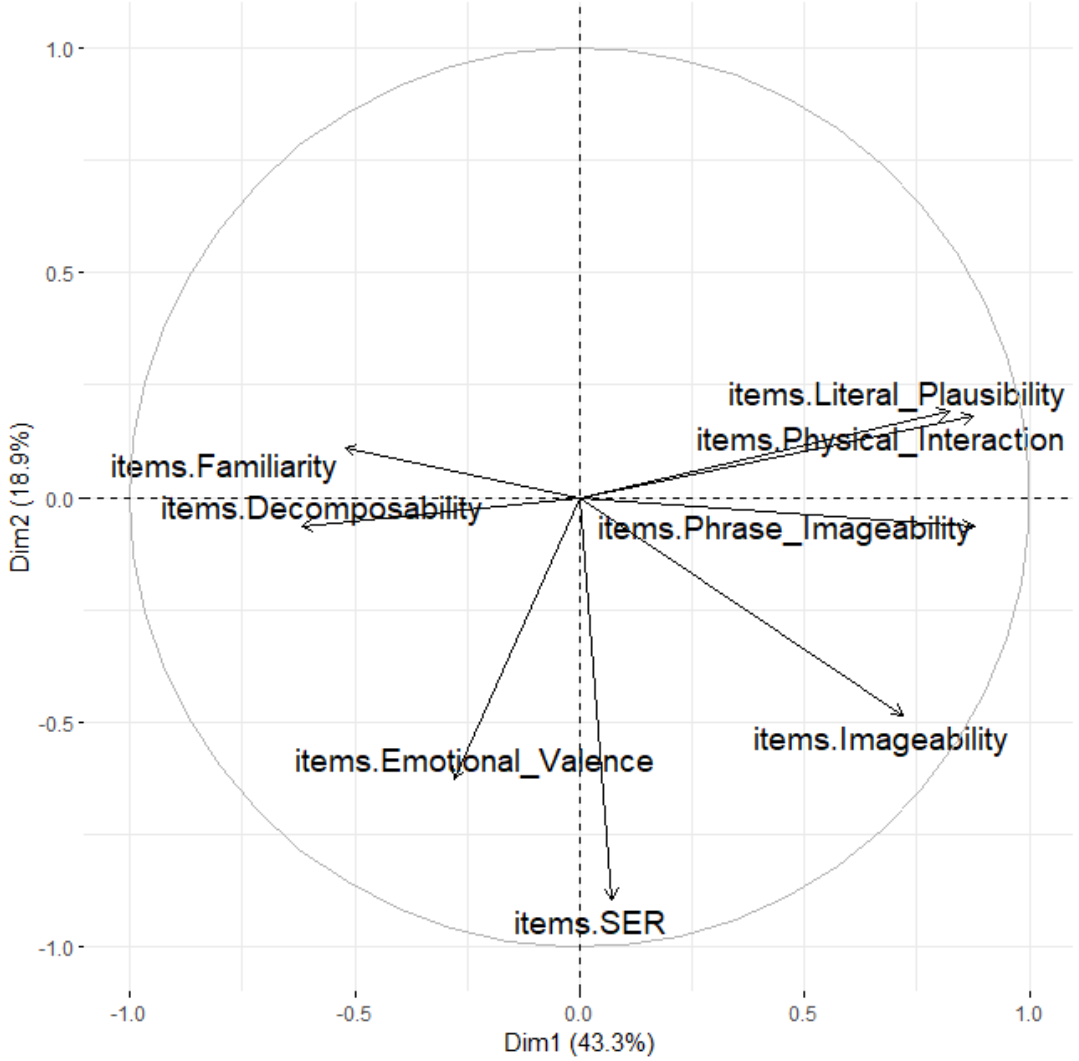
Table 2. *Means, SDs and ranges (all normalised on a 5-point scale) for the original semantic richness variables, additional phrase-level ratings, and established idiom variables (top panel), and correlations among variables (bottom panel).*

	Original ratings		Phrase ratings			Idiom variables		
	Image	SER	Image	Physical	Emotion	Fam	Decomp	Lit Plaus
Mean	3.4	2.1	3.5	2.6	3.3	3.9	2.9	2.8
SD	0.4	0.4	0.5	0.6	0.5	0.5	1.3	1.3
Range	2.4-4.4	1.3-2.9	2.3-4.4	1.8-4.3	2.1-4.2	2.5-4.7	0.5-4.9	0.8-4.9
Image		0.41**	0.56***	0.47**	-0.03	-0.45**	-0.42**	0.41**
SER	0.41**		0.04	-0.07	0.31*	-0.23	0.05	-0.12
Image	0.56***	0.04		0.84***	0.04	-0.24	-0.45**	0.76***
Physical	0.47**	-0.07	0.84***		-0.30	-0.34*	-0.38*	0.72***
Emotion	-0.03	0.31*	0.04	-0.30		0.41**	0.16	-0.18
Fam	-0.45**	-0.23	-0.24	-0.34*	0.41**		0.20	-0.25
Decomp	-0.42**	0.05	-0.45**	-0.38*	0.16	0.20		-0.42**
Lit Plaus	0.41**	-0.12	0.76***	0.72***	-0.18	-0.25	-0.42**	

Image = Imageability; SER = Sensory experience rating; Physical = Physical interaction; Emotion = Emotional valence; Fam = Familiarity; Decomp = Decomposability; Lit Plaus = Literal plausibility rating. Significant correlations are indicated as: *, p< .05; **, p < .01; ***, p , .001).

Of note here, there was a strong positive correlation between the original (word-by-word) rating for imageability and the subsequent phrase rating (r = .56, p < .001), suggesting that our original method of calculating this provided a reasonable proxy (at least for this measure). Table 2 also suggests that there may be several broad groupings within our variables: imageability, physical interaction and literal plausibility were all positively correlated with each other, and all negatively correlated with both familiarity and decomposability. Emotional valence and sensory experience were also positively correlated. To better understand the relationships among the ratings, we ran a Principal Component Analysis (PCA) using the prcomp function in R. PCA is a method for reducing multiple correlated variables down into a smaller number of dimensions, in order to visualise overall patterns. Figure 2 shows the results of this.

Figure 2. Results of Principal Component Analysis suggesting that the first component is composed of opposite effects of familiarity and decomposability (pointing left) and literal plausibility, imageability and physical interaction (pointing right). A second component consists of emotional valence and SER (pointing down).



The first principal component, which accounted for 43% of the variance in this dataset, was dominated by imageability (both ratings), physical interaction and literal plausibility operating in one direction, and familiarity and decomposability operating in the other. This suggests that, broadly, those aspects that focus attention on the physical/literal aspects of an idiom may work in the opposite direction to factors that generally are thought to facilitate idiom processing. The second principal component, accounting for a further 19% of variance, included SER and emotional valence scores. A third component (accounting for a further 15%) suggested that familiarity and emotional valence may exert broadly similar effects, and a fourth (a further 9%) was dominated by decomposability alone.

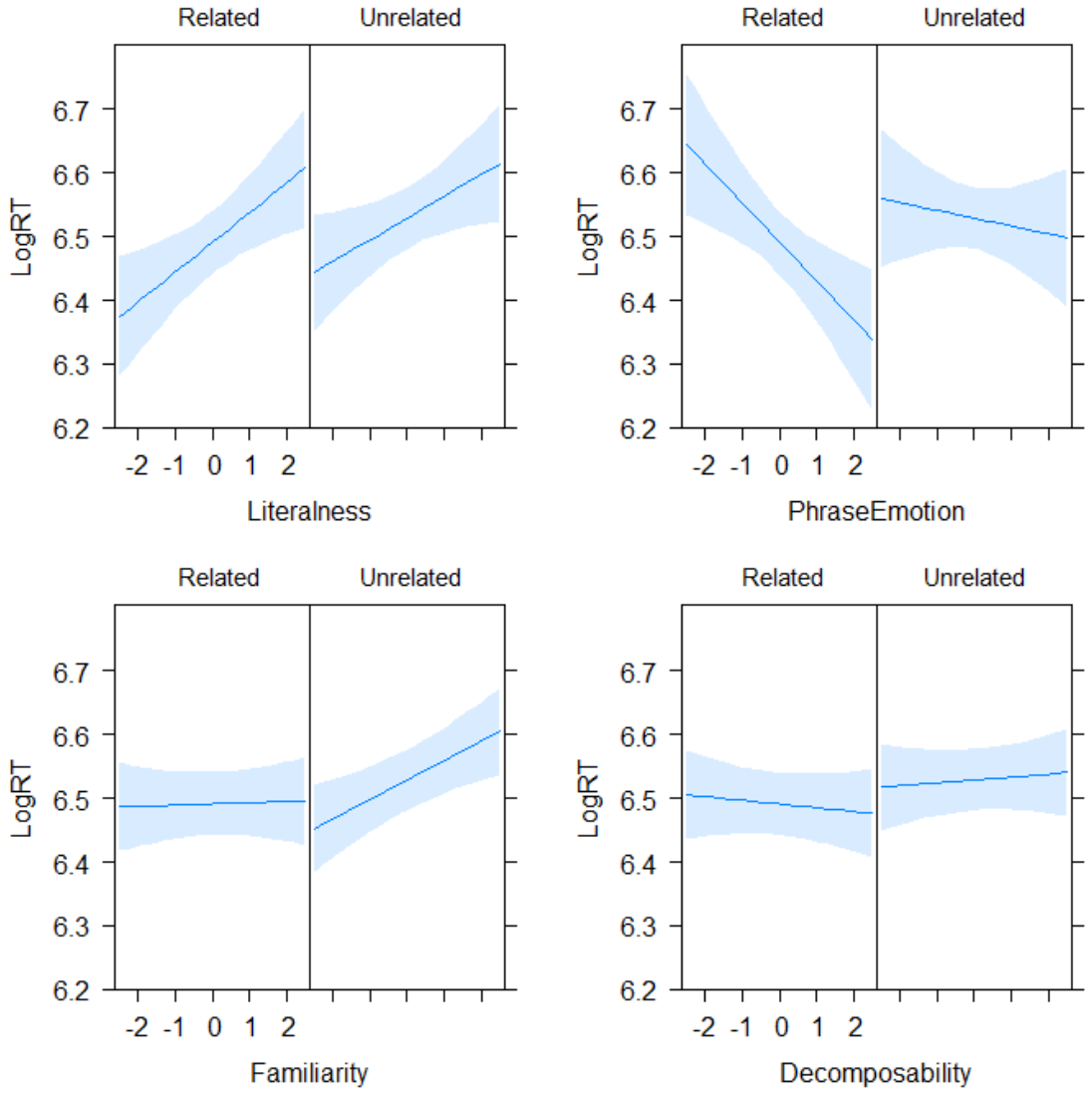
Finally, we considered the joint effects of the key variables identified in the PCA. We constructed a linear mixed-effects model including a composite literalness score, which was the mean of the word-by-word imageability, phrase imageability, physical interaction and literal plausibility scores. We also included emotional valence rating, but SER was discounted on the grounds that it made no contribution to our earlier analysis. We looked at the two-way interactions between condition and each of composite literalness, emotional valence, familiarity and decomposability. As before, target word length and frequency and trial order were included as covariates, and we included by-subject random slopes for the effect of condition. Table 3 provides the output of this model, and Figure 3 shows the effects of each of these variables.

Table 3. *Linear mixed-effects model including two-way interactions of condition with composite literalness, emotional valence, familiarity and decomposability.*

Fixed effects	*β*	SE	*t*	*p*
Intercept	7.21	0.10	97.28	.000***
Condition: Unrelated	0.04	0.01	3.43	.001**
Literalness (composite)	0.05	0.02	2.87	.005**
Emotional valence	0.06	0.02	-3.02	.003**
Familiarity	0.00	0.01	0.20	.845
Decomposability	-0.00	0.01	-0.60	.551
Target length	-0.04	0.01	-4.45	.000***
Target frequency (Zipf)	-0.09	0.01	-9.29	.000***
Trial order	-0.00	0.00	-9.64	.000***
Condition * Literalness (comp)	-0.01	0.02	-0.73	.464
Condition * Emotional Valence	0.05	0.02	2.12	.034*
Condition * Familiarity	0.03	0.01	2.64	.008**
Condition * Decomposability	0.01	0.01	0.99	.321
Random effects	Variance		SD	
Subject	0.037		0.192	
Subject * Condition	0.003		0.051	
Item	0.001		0.035	
Residual	0.053		0.230	

* p < .05; ** p < .01; *** p < .001

Figure 3. Effects plots showing influence of composite literalness (top left), emotional valence (top right), familiarity (bottom left) and decomposability (bottom right) on Log RTs for related and unrelated words.



Additionally, and motivated by some of the possibilities raised in the introduction, we checked for two further interactions in the data: an interaction of composite literalness with decomposability (on the grounds that for highly decomposable idioms where there is link between the figurative and literal meanings, literalness may actually aid

activation of the idiomatic meaning); and an interaction of either of the semantic richness variable with familiarity (on the grounds that these may exert a greater influence for less familiar phrases compared to more familiar). The addition of an interaction between composite literalness and decomposability made no improvement ($\chi^2(2) = 1.18$, $p = .554$). However, there were improvements by adding in interactions of condition, composite literalness and familiarity, and condition, emotional valence and familiarity ($\chi^2(4) = 16.88$, $p = .002$).[4] Inspection of the effects plots for these interactions suggested that for less familiar idioms, composite literalness had a more pronounced inhibitory effect on figurative meaning, while for more familiar phrases, the effect disappeared (interaction of condition, composite literalness and familiarity: $\beta = 0.06$, $t(2549) = 3.17$, $p = .002$). At the same time, for less familiar phrases there was a negligible effect of emotional valence, and as familiarity increased, emotional valence became more facilitative (interaction of condition, emotional valence and familiarity: $\beta = 0.06$, $t(2549) = 3.36$, $p < .001$).

Discussion

It is increasingly clear that in the processing of idioms, variables such as familiarity, decomposability and transparency are not independent (Carrol et al., 2018; Libben & Titone, 2008), and that they may exert an influence at different points during the comprehension process (Titone & Libben, 2014). Our results suggest that other properties also contribute, and the imageability of a phrase, the degree of physical interaction it involves, and the level of emotional valence (whether positive or negative) were all seen to exert some influence. Whilst these properties have been generally

shown to facilitate the processing of single words, as discussed in the introduction, their effect on phrases is more complex, with some (imageability, physical interaction) interfering with the activation of idiomatic meaning, and others (emotional valence) facilitating it.

The Principal Component Analysis helped to show that (at least for idioms), semantic richness cannot really be considered as a single property, and that different variables (comprising both components of semantic richness and established idiom dimensions) can be grouped together according to the effect they are expected to have on idioms. Imageability (at both the word-by-word and phrase-level), physical interaction and literal plausibility were all closely aligned, and work in the opposite direction to familiarity and decomposability. This suggests that properties that enhance the literal meaning of an idiom do slow retrieval of the figurative meaning, and that this may not simply be a question of whether a phrase is "literally plausible" as has been considered in the literature. In the initial analysis, imageability has a clear inhibitory effect on RTs for related words. In the second analysis, our composite measure of literalness (which incorporated all of imageability, physical interaction and literal plausibility) had the same effect. Whilst our experiment makes no claims about the timecourse of idiom activation, it is noteworthy that these effects manifest much later (500ms post-phrase) than the effects of literal plausibility in Titone and Libben (2014), which were observed only when a target word was presented prior to the end of the phrase.

Whilst there were clear signs of imageability and physical interaction working in the same way as literal plausibility, there was no indication of an interaction with decomposability. We raised the possibility that phrases that heighten the literal

meanings of component words may be helpful for more decomposable idioms (where the figurative and literal meanings are related), and show greater inhibition for less decomposable phrases, since the literal meaning must be completely ignored in order to interpret the phrase figuratively. We saw no indication of any such interaction, but we did see an interaction with familiarity, whereby for more familiar phrases, the inhibitory effects of literalness seemed to be much less pronounced. As well as this, we saw clear effects of emotional valence (but not sensory experience), whereby more emotionally charged phrases contributed to faster responses to figuratively related words (in line with results of emotional valence on single words, e.g. Yap & Seow, 2014). The interaction between emotional valence and familiarity suggested that this became stronger for more familiar phrases, hence the effect seems to have been to enhance the (presumably most salient) figurative meaning. Logically, only well-known phrases could be seen as having strong meanings, and the third component of the PCA was dominated by the effects of familiarity and emotional valence, which supports the idea that these may go hand-in-hand.

Our results are consistent with the constraint-based account (Titone & Connine, 1999; Libben & Titone, 2008), whereby multiple factors combine to affect how an idiom will be understood. Titone and Libben (2014) proposed that idiom meaning is always retrieved to some degree (c.f. Caillies & Declerq, 2010, who compared decomposable idioms with novel metaphors) but that factors such as decomposability, conventionalisation, familiarity, etc. will affect how straightforwardly this occurs. Our data provides preliminary evidence that those aspects of semantic richness that relate to the physical and perceptual characteristics of idioms may play an important role in rendering the literal interpretation more difficult to ignore. Of note, this seems to be

more complex than simply whether or not a phrase is/is not literally plausible. Several studies have addressed the question of how literal meaning contributes to idiom meaning (e.g. Cacciari & Tabossi, 1988; Hamblin & Gibbs, 2000; Smolka et al., 2007), and the question may also be relevant in the context of language impairment, where an inability to inhibit literal meanings may contribute to difficulties in processing figurative language in conditions such as Alzheimer's disease (e.g. Papagno, Luchelli, Muggia & Rizzo, 2003; Rassiga, Luchelli, Crippa & Papagno, 2009) and aphasia (e.g. Papagno & Caporali, 2007; Papagno & Genoni, 2004). A small number of studies have also investigated the relationship between emotional arousal and figurative language (e.g. Citron & Goldberg, 2014; Citron et al., 2016), and the clear contribution of emotional valence to our results suggests that this might present a fruitful avenue for further investigation.

Our results speak only to the perceptual aspects of semantic richness discussed in the introduction, but we can speculate on the other elements relating to connectedness within the semantic network. Mueller and Gibbs (1987) found that the meaning of literally plausible idioms was accessed more quickly than unambiguous (figurative only) phrases, which may lend credence to the "number of senses" variable as a facilitative one, just as in single word processing (e.g. Rodd, 2004; Woollams, 2005). As per the Construction Integration model (Kintsch, 1998 – alluded to earlier, and cited by Caillies and Butcher, 2007), when a phrase requires the component words themselves to make some contribution to the meaning (e.g. *spill the beans*), greater connection with the semantic neighbourhood may facilitate the activation of both literal and figurative meanings, whereas when this is not required, effects may be less apparent. For non-decomposable examples such as *kick the bucket*, where the

component words do not directly contribute to the meaning, aspects of semantic richness that reflect interconnectedness with the semantic neighbourhood may have no effect on the figurative meaning, whereas more decomposable examples may be facilitated. Ultimately, increasing familiarity may override other properties (e.g. Abel, 2003; Carrol et al., 2018; Keysar & Bly, 1995, 1999), or at least mean that their effects manifest only for less well-known items (Titone & Libben, 2008), where more effort is required to actively work out the intended meaning. We saw some evidence of this in the interactions with familiarity in our data, where interference with the figurative meaning seemed to be negligible for the most familiar phrases. Comparing our results to other kinds of figurative language, Al-Azary and Buchanan (2017) found an interaction between concreteness and semantic neighbourhood density whereby only metaphorical topic-vehicle pairs from dense semantic neighbourhoods showed an effect of concreteness (more abstract topics were judged as more suitable, and understood more easily), while for less dense neighbourhood, concreteness had no effect. They also discuss their results in terms of a need to suppress irrelevant connections, which is more difficult for concrete topics with many near neighbours in semantic terms.

Overall, our results suggest that constructs such as literal plausibility may be seen as encompassing a range of micro-features that determine how easily a figurative meaning might be activated. As well as simply whether a phrase is "plausible" as a literal proposition, we may need to consider the relative dominance of the figurative and literal meanings (which will vary from speaker to speaker), as well as the physical characteristics identified in our study. On a practical level, this has implications for future idiom studies, where item choice may be unintentionally compromised if a broad range of features are not considered and balanced. We acknowledge here that certain

aspects of our methodology may restrict how generalisable our results are. In our stimuli, all word responses in the lexical decision task were preceded by an idiom, hence it is possible that participants may have entered some kind of "idiom mode" in how they approached the experiment, especially given the context free presentation of the items. There was also no literal condition, so we don't know the extent to which the interference we saw was actually a result of heightened attention to the literal meaning. Since our aim was to specifically look at the relative effect of semantic richness on figurative activation, we do not see this as invalidating our findings, but we do highlight that the results should be interpreted with caution.

These caveats notwithstanding, from a processing point of view, it is apparent that the range of variables considered here operate in different ways in their effect on how idioms are processed, with some interfering with the idiomatic meaning (presumably by drawing focus to the literal aspect of idioms), and others enhancing the salience of the figurative meaning. Increased attention to the literal and physical properties of a phrase may have a cost in that the degree of abstraction for an idiom is reduced, making the figurative meaning less apparent. At the same time, aspects that enhance the figurative meaning attenuate this, and emotional valence in particular may be an under-estimated aspect of this field of study.

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Appendix – stimuli used in the experiment

Idiom	**Related target**	**Unrelated target**
He blew a fuse	anger	height
He dropped the ball	mistake	orange
He foot the bill	money	ground
He held the fort	protect	marble
He lost his cool	temper	action
He lost his nerve	panic	likely
He missed the mark	failure	threat
He pulled her leg	teased	sleeve
He shouldered the blame	liable	pierce
He threw in the towel	defeat	differ
He twisted her arm	coerce	nature
She covered her tracks	secret	marine
She dropped a bomb	surprise	dealer
She had a ball	enjoy	mirror
She killed the time	wasted	castle
She lost her head	fury	artist
She pushed his buttons	provoke	thesis
She rocked the boat	disrupt	absent
She worked of steam	release	packet
They bent the law	cheater	tiptoe
They weathered the storm	endure	jacket
He bit the dust	perish	marine
He blew her cover	expose	tiptoe
He cleared his name	freed	artist
He lifted her spirits	happy	mirror
He lost his touch	forget	dealer
He pulled the plug	ended	thesis
He smelled a rat	suspect	action
He stole her thunder	usurp	castle
He took a fancy	liking	ground
He took the plunge	braved	table
He turned the tables	reverse	orange
It called to mind	remind	differ
It slipped his mind	forgot	sleeve
She called the shots	leader	likely
She showed her cards	reveal	height
She spoke her mind	honest	absent
She stole the show	focus	pierce
she took a hint	infer	nature
She went to town	commit	packet
They cleared the deck	tidied	marble
They sang her praises	flatter	threat

Footnotes

[1] For all items we measured target frequency in both the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA), then calculated a score for each on the Zipf scale (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014), which expresses frequency on a logarithmic scale indicating relative frequency of occurrence considering the size of the corpora (e.g. a Zipf score of 1 equates to a frequency of 1 per 100 million words; a score of 2 equates to a frequency of 1 per 10 million words, etc.) We compared BNC and COCA scores and found these to be very highly correlated for our items (r = .96, p < .001), hence we calculated a mean Zipf score based on these two scores for each item.

[2] We used a prime-target delay of 500ms since the analysis in Titone and Libben (2014) suggested that figurative meaning steadily accrues for around 1000ms after an idiom has been heard. We therefore wanted to allow time for figurative meaning to develop, to best enable us to observe any effects of semantic richness on this.

[3] Idiom frequency was collected in the same way as for target words, by calculating Zipf scores based on BNC and COCA frequency counts for the lemmatised version of each phrase. The correlation between BNC and COCA values was high (r = .75, p < .001), so we again used a frequency score based on the mean of these two values. Interestingly, there were no correlations between familiarity ratings and either BNC frequency (r = .09, p = .59) or COCA frequency (r = .14, p = .39).

[4] Model comparison showed that the addition of separate three-way interactions involving each of the semantic richness variables was an improvement over an interaction with either composite literalness (χ^2 (2) = 12.27, p = .002) or emotional valence (χ^2 (2) = 9.90, p = .007) alone.